BELLCOMM, INC.

SUBJECT: Orbital Altitude Considerations for AAP-4 - Case 600-1

DATE: April 5, 1967

FROM: V. J. Esposito

ABSTRACT

The current AAP-3/AAP-4 dual rendezvous mission calls for an initial injection altitude of 240 nm for the LM/ATM (AAP-4). In this memorandum other alternative altitudes ranging from 130 to 240 nm are examined to see what improvements in total mission payload might be achieved by lowering the AAP-4 initial altitude.

The net payload increases as the AAP-4 altitude is lowered with the 130 nm altitude showing a maximum payload gain of 7390 lbs. Comparative tabulations of the payload variation and propellant requirements are given, and a plot of total payload vs. initial AAP-4 altitude is shown.

Other factors that influence the selection of the optimum initial altitude, such as rendezvous phasing, propellant tankage capacity, and payload transfer from AAP-3 to AAP-4, are mentioned but not discussed in detail.

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MEMORANDUM FOR FILE

In its current configuration, the AAP-3/AAP-4 dual-rendezvous mission calls for the three space vehicles involved to be situated initially in circular orbits at the following altitudes:

CSM (AAP-3)	120 nautical miles
LM/ATM (AAP-4)	240 nautical miles
Orbital Workshop (AAP-2)	250 nautical miles

From this set of initial conditions, the CSM first transfers to a 230 nm orbit and then rendezvous with the LM/ATM, the final gap of 10 miles between the vehicles being closed during the rendezvous maneuver. After an appropriate phase adjustment, the CSM/LM/ATM combination enters an elliptical equi-period orbit until the proper time for the final rendezvous with the Orbital Workshop (OWS). This final maneuver is accomplished by the two vehicles individually, with first the LM/ATM and then the CSM closing the 10 mile gap from 240 to 250 nm during rendezvous.

In considering the set of initial conditions tabulated above, the following points can be noted:

1. The Orbital Workshop altitude of approximately 250 nm is fixed by the parameters of the previous AAP-2 flight and the time of the AAP-3 launch. An initial altitude of 260 nm has been selected for the AAP-2 flight, and during the currently planned six-month time interval between AAP-2 and AAP-3 the OWS orbit can be expected to decay approximately 10 nm to the 250 nm altitude shown here.

2. The initial CSM (AAP-3) circular orbit altitude is also fixed at a minimum of 120 nm, based on orbital lifetime considerations for the mission. Current mission planning for the AAP-3/AAP-4 dual flight calls for the CSM to be placed in as low an orbit as possible (to permit the maximum useful in-orbit payload) but that the

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lifetime of the initial CSM orbit be sufficient to allow for a one or two day delay in the launch of the target vehicle, AAP-4.

3. The initial AAP-4 (LM/ATM) circular orbit altitude of 240 nm does not reflect either of the above mentioned constraints. This comparatively high initial altitude does make the problem of proper rendezvous phasing between the CSM and LM/ATM somewhat easier to resolve, since the errors in phasing caused by initial launch delays can be made up during the height adjustment maneuvers which raise the CSM from 120 to 230 nm in altitude. An additional advantage of operational simplicity is also inherent in the 240 nm LM/ATM orbit, since no major height adjustment maneuvers are required for the CSM/LM/ATM combination between the initial rendezvous of the CSM with the LM/ATM and the final individual rendezvous at the OWS. These advantages in rendezvous phasing and operational simplicity are gained, however, at the expense of the total payload delivered to the OWS.

In order to determine what improvement in total payload might be achieved by using an initial AAP-4 altitude of other than 240 nm a simplified two-body analysis of several selected alternatives was carried out. Keeping the initial CSM and the OWS altitudes fixed at 120 and 250 nm, respectively, the injection altitude for the LM/ATM (AAP-4) was varied from the initial level of 240 miles down to a minimum of 130 miles* in four steps. For each of these steps, the AAP-4 injection payload was increased to the maximum capacity of the uprated Saturn I launch vehicle and the necessary maneuvers were calculated to achieve the final desired configuration at 250 miles.

A comparative tabulation of the five cases, including the original 240 nm mission and showing the total payloads at various critical points in the mission, is presented in Table 1. Table II shows the combined SPS and RCS fuel expended during each phase.

A plot of the variation in total payload at OWS altitude vs. the initial AAP-4 injection altitude is given in Figure I. This curve, as anticipated, essentially parallels (with an appropriate change in scale) the curve for uprated Saturn I payload capability as a function of altitude.

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*130 nm was selected as a lower limit to allow a nominal 10-mile delta h for CSM rendezvous with the LM/ATM.

Not all of the additional AAP-4 weight can be considered as a net gain, of course, since a portion of this increase in payload is offset by the additional SPS propellant that must be carried on the CSM (AAP-3) in order to lift the combined CSM/LM/ATM the extra distance to the Orbital Workshop. Nevertheless, each lowering of the AAP-4 injection altitude resulted in a significant net payload increase for the final configuration at OWS altitude. The maximum payload was obtained by using the lowest AAP-4 altitude of 130 miles.

Inherent in this concept of increasing the AAP-4 payload is the requirement that at least some portion of the original AAP-3 payload be suitable for transfer to the AAP-4 vehicle, since an amount equal to the weight of the additional SPS fuel required must be removed from AAP-3.

A number of simplifying assumptions and propellant expenditure estimates were required in order to structure each alternative mission realistically. These included the following:

1. The latest available delta V and propellant requirements from appropriate MSC/MPAD memoranda* were used as a base for all estimates. In particular, the "control" case of 240 nm was calculated first to provide a yardstick for the succeeding cases.

2. Delta V requirements for the numerous 10-mile delta h rendezvous situations were scaled linearly from the amounts required for the "control" case of 240 nm. Variations in weight as well as variations in altitude were accounted for.

3. No attempt was made to estimate additional propellant requirements to cover rendezvous and docking dispersions or additional phasing maneuvers that might be required. Where the original MPAD figures for the 240 nm case contained some allowances for dispersion, these were included (properly scaled) in all cases.

It is recognized that many factors in addition to final total payload must be considered in selecting the orbital altitudes to be used for this dual-rendezvous mission. For

*MSC/MPAD Memorandum 67-FM14-8 dated February 14, 1967 example, the probability of launch delays and their subsequent effects on rendezvous phasing maneuvers must be considered. Also, as noted earlier, the increased AAP-4 payload can only be gained at the expense of a slight reduction in the AAP-3 payload; and this will require the transfer of some of the original payload from AAP-3 to AAP-4. Finally, the increased LM/ATM weight means an increased LM RCS propellant budget for the LM/OWS rendezvous, which may strain or exceed the LM tankage capacity.

V. J. Esposito

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Attached:
Tables I and II
Figure 1

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TABLE I

AAP-3/AAP-4 Payload Schedule - lbs.

Mission Events	Initial LM/ATM Injection Altitude - NM				
	240	212.5	185	152.5	130
CSM in 120 nm circular orbit	35677	35677	35677	35677	35677
CSM @ LM/ATM rendezvous altitude	33682	33969	34286	34633	34901
LM @ injection altitude*	24180	26450	28950	31450	33080
CSM/LM-ATM total after 1st rendezvous	57862	60419	63236	66083	67981
CSM/LM-ATM @ 240 nm altitude	57862	59855	62077	64134	65447
CSM/LM-ATM in equi-period orbit	57172	59144	61344	63380	64680
CSM final @ OWS	32405	32112	31817	31362	31037
LM/ATM final @ OWS	23632	25865	28324	30782	32390
Total payload @ OWS	56037	57977	60141	62143	63427
Net payload increase over 240 nm case	-	+1940	+4104	+6106	+7390

*After deducting 5550 lbs. for SLA, S-IVB modifications, and Nosecap.

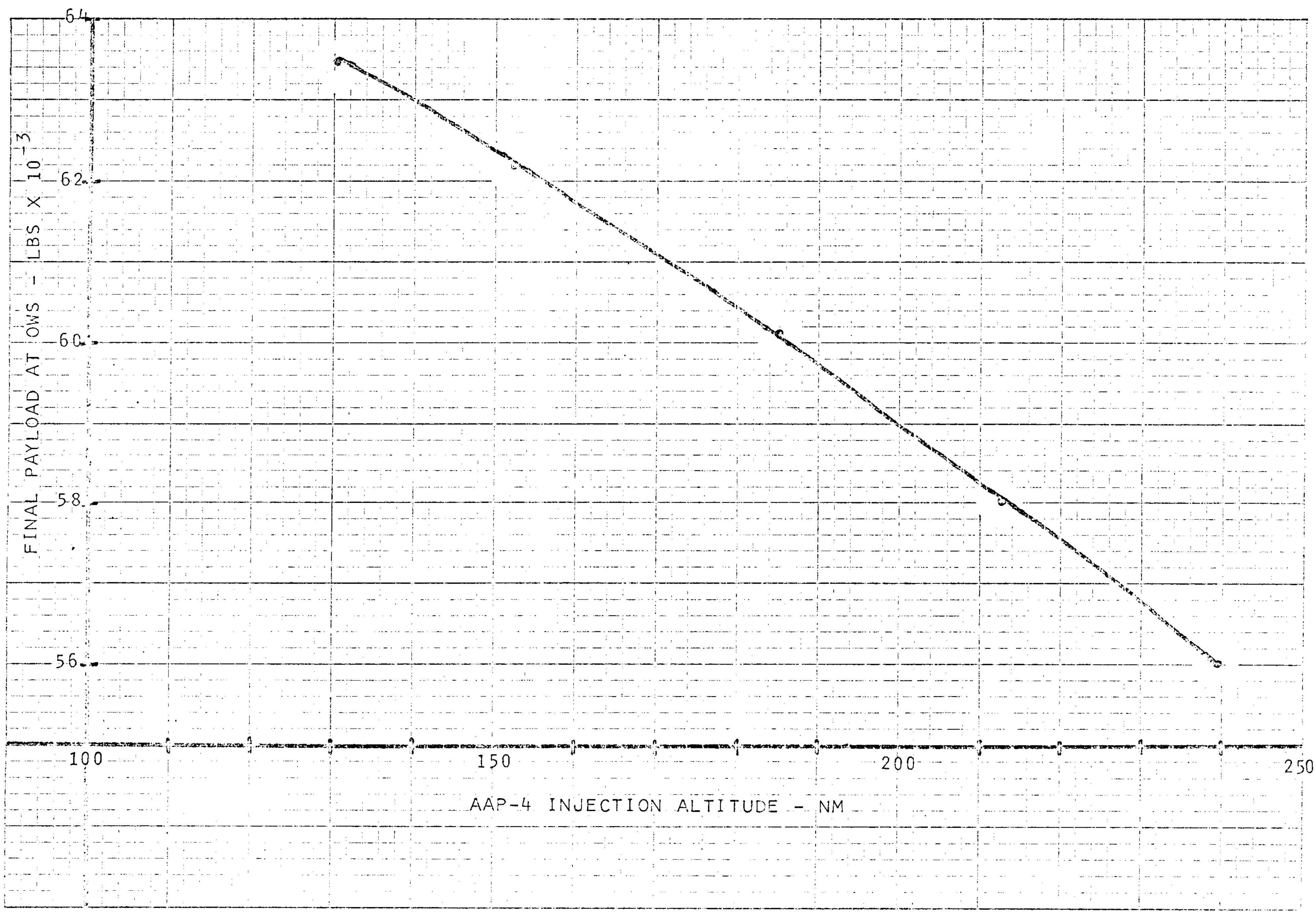
TABLE II

AAP-3/AAP-4 ΔV & Propellant Budget

	Initial LM/ATM Injection Altitude - NM									
	240		212.5		185		157.5		130	
Mission Events	ΔV*	Prop**	ΔV	Prop	ΔV	Prop	ΔV	Prop	ΔV	Prop
CSM transfer to LM/ATM altitude	386	1317	292	1014	195	681	83	303	-	-
CSM rendezvous with LM/ATM (Δh = 10)	75	678	76	694	77	710	78	741	80	776
CSM/LM transfer to 240 nm	-	-	94	564	187	1159	303	1949	382	2534
Equi-period maneuver	72	690	72	711	72	733	72	754	72	767
LM/ATM rendezvous with OWS	75	548	75	585	75	626	75	668	75	690
CSM rendezvous with OWS	75	587	75	582	75	577	75	569	75	563
TOTAL PROPELLANT		3820		4150		4486		4984		5330
Net propellant increase over 240 nm case***	-	-	+330		+666		+1164		+1510	

*ft/sec
**lbs
***Also represents minimum AAP-3 to AAP-4 payload transfer required

FIGURE 1. AAP-3/AAP-4 PAYLOAD



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